CROP DAMAGE BY BLACKBUCK *ANTILOPE CERVICAPRA* AT ROLLAPADU WILDLIFE SANCTUARY, ANDHRA PRADESH[1]

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(*With one text-figure*)

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The paper discusses crop damage by blackbuck *Antilope cervicapra* at Rollapadu Wildlife Sanctuary (RWS), Andhra Pradesh, based on studies carried out during 1993-1994. Damage was recorded in 8 of the 20 crop species studied in the vicinity of the Sanctuary. Damage was high in foxtail millet, sorghum, and in the irrigated summer greengram and blackgram crops, moderate in redgram, groundnut and greengram (monsoon crop), low in cotton and minimal in sesamum. The extent of damage depended on many factors, which are discussed. Damage was negatively correlated to distance from the blackbuck area for five of the six species (except for cotton) studied. Except for sesamum, which is thrashed to the ground by male blackbuck, the other species are eaten. The damage recorded in cotton is likely to be due to livestock, and probably some of the damage recorded for the other crops could also have been contributed by livestock. Thus, it is advised that claims for crop damage compensation by farmers should be scrutinised carefully before approval. Measures to stop or reduce crop damage are suggested.

INTRODUCTION

The blackbuck *Antilope cervicapra* is a major component of the semi-arid grassland ecosystem of the plains of the Indian subcontinent. It is known to take to crop-raiding (Ranjitsinh 1989, Chauhan and Sawarkar 1989, Prakash 1990, Prasad and Ramana Rao 1990). In some areas, crop raiding by blackbuck is a recent problem due to the increase in blackbuck numbers after recent conservation steps for the animal and/or the habitat (Rahmani 1985, Schultz 1986, Chauhan and Sawarkar 1989, Chauhan and Singh 1990, Manakadan and Rahmani 1993, Chandra 1997). These crop depredations antagonise farmers, resulting in a negative attitude towards blackbuck conservation, and conservation of wildlife in general.

During a U.S. Fish and Wildlife Service sponsored study by the BNHS and the Centre for Wildlife and Ornithology, Aligarh Muslim University, on the ecology of the grasslands of RWS, we undertook a study on the crop damage by blackbuck to know which species were being affected, the nature of the damage, and to some extent, attempted to quantify the extent of the damage. Special efforts were made to check if the damage was by blackbuck, as we realised that some farmers were exaggerating or wrongly attributing livestock-caused crop damage to blackbuck. This was either due to ignorance, to get monetary compensation for crop damage, or to give a bad name to the Sanctuary so as to demand grazing rights within the protected enclosures or to get back the land lost by farmers and graziers when the Sanctuary was established.

It is hoped that the results and recommendations of this study will be used as a management strategy to decrease the problem of crop damage by blackbuck at Rollapadu and in other sanctuaries which have the same problem.

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Study Area

Rollapadu is situated 18 km southeast of Nandikotkur (15°58' N & 78°18' E), Kurnool dist., Andhra Pradesh. It lies in the plains between the Nallamalai and Yerramalai hills, at an altitude of about 200 m. The terrain is gently undulating with predominantly poor red soils. The region is semi-arid with an average annual rainfall of 668 mm, received from both the Southwest and Northeast monsoons. Summer peaks at 42°C (April and May) and winters are mild (17°C).

Rollapadu (area: 6.14 km^2) had its origin in 1982, after the 'rediscovery' of the great Indian bustard *Ardeotis nigriceps,* and was declared a Sanctuary in 1988. The Sanctuary proper consists primarily of three grassland plots or enclosures: Enclosure-I: 320 ha, Enclosure-II: 40 ha and Enclosure-III: 120 ha (Fig. 1). These enclosures are demarcated by trench-cum-mound (TCM) walls to exclude livestock and people. However, Enclosure-III was opened to grazing after protests by the locals about the lack of sufficient grazing land for their livestock. The extent of protection to Enclosure-II varied from year to year. The three enclosures are separated from each other by grazing land and crop fields. The other major fauna of the Sanctuary include the lesser florican *Sypheotides indica*, harriers (largely *Circus pygargus* and *C. macrourus*), blackbuck *Antilope cervicapra*, wolf *Canis lupus*, jackal *Canis aureus*, Indian fox *Vulpes bengalensis* and common Indian monitor *Varanus bengalensis*. For more details of the Sanctuary, see Manakadan and Rahmani (1989, 1993 &1997).

BLACKBUCK

Population: The blackbuck is one of the many grassland species that has benefited from the conservation measures intended for the great Indian bustard. According to the locals, the area always harboured blackbuck, which were hunted by locals and outsiders. The population in 1985 was 17 individuals, which rose to around 35 by 1987, and was about 300 animals during the present study (Manakadan and Rahmani 1989, 1993, 1997).

Movements: The onset of the southwest monsoon in June/July heralds the movement of blackbuck into Enclosure-I, and this congregation is seen till about January. This is due to a combination of rich grazing grounds, lack of human and associated disturbances inside the enclosure, coupled with the overgrazed conditions in the surrounding grazing land and heavy disturbance there. However, blackbuck move into crop fields late in the evening and return to the enclosure early in the morning. By the middle of January, the grasslands dry up, the harvest in the surrounding crop fields is almost over and most of the livestock (especially sheep) migrate to other areas. The blackbuck then disperse over a wide area, moving into the surrounding grazing land and harvested or fallow fields. Thus the density of blackbuck is low in the enclosure from February till the onset of the monsoon.

While in the grazing land, the blackbuck mainly frequent areas to the east and northeast of Enclosure-I and to a lesser extent south-west of Enclosure-III (Fig. 1). This is due to the presence of extensive grazing land and less human and associated disturbances in these areas compared to other parts of the grazing land. In general, blackbuck tend to avoid areas in the vicinity of villages, intensive agriculture zones and where there is a regular movement of humans or vehicles.

CROPS AND CROPPING PATTERN

The sowing of redgram, groundnut, foxtail millet, sesamum, greengram, blackgram, cowpea, Deccan hemp, cotton and paddy commences with the onset of the Southwest monsoon. The harvest depends on the duration of the crop (Table 1). Sorghum and Bengal gram are sown in October/November, the latter is generally sown in harvested and re-ploughed

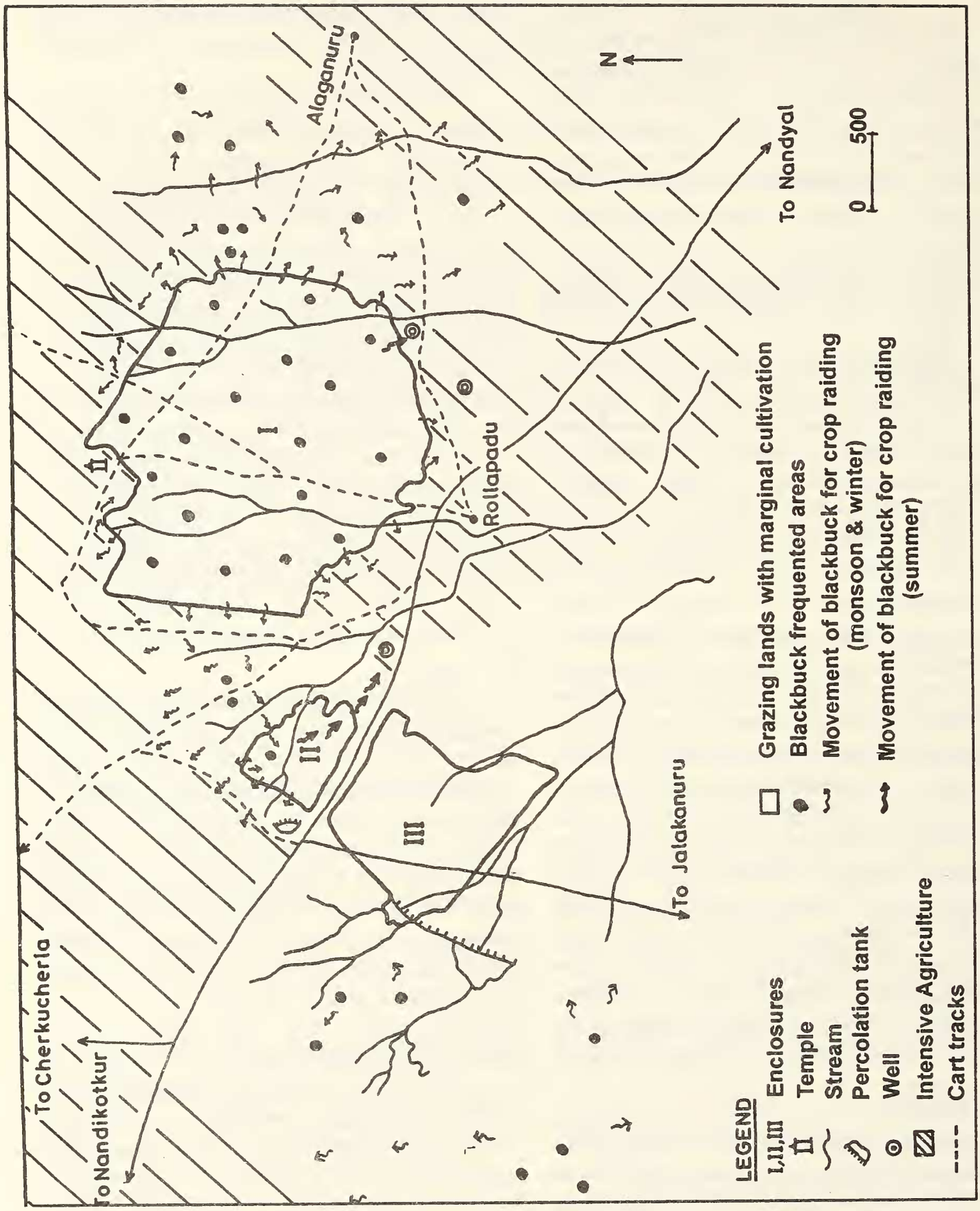

Fig. 1: Map of Rollapadu Wildlife Sanctuary showing distribution and movement of blackbuck into crop fields

TABLE 1
CROPS AND CROPPING PATTERN AROUND ROLLAPADU WILDLIFE SANCTUARY

	Crop	Scientific Name	Approximate Acreage (Percentage of all crops)	Sowing Period	Harvest Period
1.	Sorghum	*Sorghum bicolor*	20%	Oct.	Jan./Feb.
*2.	Groundnut	*Arachis hypogea*	20%	Jun./Jul.	Nov.
3.	Cotton	*Gossypium arboreum*	20%	"	Mar.
*4.	Redgram	*Cajanus indicus*	10%	Jun./Jul.	Jan.
5.	Sesamum	*Sesamum indicum*	10%	"	Dec.
6.	Sunflower	*Helianthus annus*	5%	"	Nov./Dec.
7.	Foxtail Millet	*Setaria italica*	5%	Jun./Jul.	Oct.
8.	Paddy	*Oryza sativa*	-	"	Dec.
9.	Bengal gram	*Cicer arietinum*	-	Nov.	Jan.
**10.	Greengram	*Vigna radiata*	-	"	Dec.
**11.	Blackgram	*Vigna mungo*	-	"	Dec.
**12.	Cowpea	*Vigna sinensis*	-	"	Dec.
13.	Deccan Hemp	*Hibiscus cannabinus*	-	"	Dec.
14.	Mustard	*Brassica campestris*	-	"	Mar.
15.	Cucumber	*Cucumis sativus*	-	Jun./Jul.	Nov/
16.	"	*Cucumis sp.*	-	"	"
#17.	Chillies	*Capsicum spp.*	-	"	Apr.
#18.	Brinjal	*Solanum melanoxylon*	-	"	"
#19.	Tomato	*Lycopersicon esculentum*	-	"	"
20.	Mulberry	*Morus alba*	-	(perennial)	

* Grown in winter also if irrigation is available. ** Grown in summer also if irrigation is available

\# Generally irrigated by wells. (-) Forming rest of the 10%.

paddy fields. Where irrigation from wells is available, a second crop of groundnut may be sown in November, along with some short duration grams. However, irrigation is mainly intended for growing vegetables like brinjal, tomato and chillies. Most of the fields are bare after February and most of the wells dry up by April, hence there are hardly any crop fields from April till the onset of the monsoon in June/July.

Sorghum, foxtail millet, Bengal gram, sunflower, groundnut, cotton and paddy are grown in pure stands. Redgram, sesamum, greengram, blackgram, cowpea, cucumber and Deccan hemp are generally grown in rows in the fields of cotton and groundnut. Sorghum may also be sown in the fields of groundnut after the harvest, and thus would be growing in between the rows of the existing redgram.

The soil characteristics and soil depth determine the intensity of cultivation, viz., intensive, marginal or isolated fields (see Fig.1). During the crop season, there is a regular stream of workers into crop fields — for weeding, tilling, applying fertiliser or pesticide, and harvesting of early crops. Due to this, intensively cultivated patches would have more human disturbance (for blackbuck) than marginal or isolated crop fields.

In Table 1, the crop and cropping pattern around RWS are given. Only the approximate percentage acreages of the crop species (according to our estimates) are given, as the

information obtained from the local records was found to be incorrect when checked in the field. It was not possible to map the crop fields as the area was large, the work would be time consuming, and was further hampered by the mixed cropping in many fields and crop rotation within a growing season.

Methodology

Estimation of crop damage by wildlife is difficult to quantify, may involve measures of numerous variables and different methods of sampling, and the estimation can be based on parts of the plant, whole plants, or whole plots (Mower *et. al.* 1997). Crop damage estimation at RWS was more problematic as we were dealing with as many as 20 crop species, many with different growing seasons. We defined damage as the percentage of damage recorded in the samplings, based either on the number of quadrats laid or number of plants assessed for damage. The extent of damage to each plant or parts of the plant was not quantified, instead we qualitatively recorded which part of the plant was affected. The methodology adopted for our study was as follows:

In each sampling, we recorded the number of plants in the field or quadrat, numbers damaged, parts damaged and the height and stage of the crop. The sampling was in a straight line, radiating at many points away from Enclosure-I, and stopping after a few quadrats when damage was not being recorded. During subsequent visits to the fields at different stages of the crops, new areas of the fields were sampled, and not where damage had been recorded during earlier sampling (earlier damaged plants could generally be recognised by their pruned appearance and shorter heights). Three types of sampling methods were adopted due to the varying acreages of the different crop species.

1. In crop species where the number of fields were abundant, sampling by quadrats (1 m^2) was adopted, and damage was assessed for the total number of quadrats laid out, the number of quadrats in which damage occurred and the number of plants damaged in these quadrats.

2. For species where only a few plants were present (e.g. sesamum, Deccan hemp, greengram) in a field (as in the case of mixed cropping), quadrats were not used. Instead, all the plants or a fixed number in the crop field were assessed for damage.

3. When there were only a few fields of a crop species, then all the available fields (and the plants in the field) were checked for damage.

Thus the sample sizes for the different crops were as follows:

Quadrats: Groundnut - 96: 2267; Redgram - 205: 2515; Foxtail millet - 75: 5093; Cotton - 106: 1557; and Sorghum - 159: 1694 (0-30 cm height); 192: 2256 (31-75 cm height) and 273: 3040 (>76 cm height). *(Note: The values indicate the number of quadrats laid and the total number of plants assessed for damage).*

Plants: Where all the plants in a field or a fixed number were assessed for damage: Sesamum - 3313, Greengram - 210 (monsoon), 627 (summer); and Blackgram - 40 (monsoon), 446 (summer). *(Note: The values indicate the number of plants sampled).*

Fields: Where all the available fields (and all the plants in the fields) were checked for damage: Paddy - 7; Bengal gram - 2; Mulberry -1; Mustard - 1; Cucumber spp. - 3; Sunflower - 14; Deccan hemp - 9; Cowpea - 3; Chillies - 1; Brinjal - 1; Tomato - 1 *(Note: The values indicate the number of fields sampled).*

Distances of the fields from the blackbuck area were noted. Preventive measures taken to control crop damage were recorded either from observations or enquiries from farmers. Presence of blackbuck and livestock in crop fields, either from sightings or signs (hoof prints and faeces) were noted to know if the damage was by blackbuck or livestock. The data presented is based on one cropping season: 1993-1994.

Data Analysis: Except for jowar, where

TABLE 2
DETAILS OF CROP DAMAGE AROUND ROLLAPADU WILDLIFE SANCTUARY

Crop	Parts Damaged	Stage of Crop	Remarks
Damaged			
Sorghum	shoot & leaves	GS	
Foxtail Millet	shoot, leaves & fruit	GS, FF	
Groundnut	shoot & leaves	GS	
Redgram	shoot	SS	
Greengram	shoot & fruits	FF	
Blackgram	shoot & fruits	FF	Few samples.
Sesamum	whole plant	FF	Thrashed to the ground by male blackbuck
Cotton	shoot	GS	Damage by livestock?

SS = Seedling Stage GS = Growing Stage FF = Flowering & Fruiting Stages

Not damaged: Deccan Hemp, Bengalgram, Cowpea, Paddy, Mustard, Cucumber (two species), Mulberry , Sunflower, Chillies, Brinjal, Tomato.

analysis was done for different height classes, the other species were not broken into different stage or height classes for damage assessment. This was because the other species had already passed the seedling stage when the studies started. Further, the growing stages of these species were not clearly defined and extended, as in sorghum. However, general notes on these species, to see at what stages the damage occurred, were taken and are used non-quantitatively in Table 2.

For correlation analysis of the extent of damage with distance from the blackbuck frequented area, only the fields where there were no barriers (such as deep TCM walls, intervening dense natural vegetation, buffers of other extensive stands of preferred/non-preferred crop species) and where crop protection measures were not adopted, were used for analysis. Greengram, blackgram and sesamum were not included, as the first two species usually have buffers of taller crops around them. In the case of sesamum, it is not eaten, but thrashed down by male blackbuck. Hence, the distance to damage correlation was attempted only for groundnut, redgram, foxtail millet, sorghum and cotton.

RESULTS

Of the 20 crops studied, damage was recorded in 8 species, namely sorghum, foxtail millet, jowar, groundnut, sesamum, greengram, blackgram and cotton (Table 2). Of these, it is doubtful whether the damage recorded in cotton was caused by blackbuck. Though damage was not recorded in two members of Cucurbitaceae, seedlings of one (or both?) of these plants were recorded growing in blackbuck middens. Of the 8 species of crops, 7 were used as food. Sesamum was damaged by male blackbuck thrashing plants to the ground with their horns.

The stage of the crop and parts eaten/damaged differed according to the species (Table 2). Damage was high in foxtail millet and sorghum, irrigated summer crops of greengram and blackgram, moderate in redgram, groundnut and monsoon crop of greengram, low in cotton and very low in sesamum (Table 3). Frequency of damage (quadrat-wise damage) showed higher values than intensity of damage (plant-wise damage) for all crops, indicating that the damage is spread out over the fields. A good proportion of damage recorded in

redgram was possibly due to cattle, as many cases of damage were recorded in freshly tilled fields. In sorghum, the only crop species for which damage was quantified on a temporal scale, damage was lowest when the crop was in the range of 31-75 cm tall. Locals say sorghum becomes toxic during this stage and livestock feeding on it become sick or even die.

Though the paddy, sunflower and mulberry fields adjoined the enclosure and the blackbuck were not hindered by any barriers to visit these crops, damage was not recorded. This shows that blackbuck certainly do not eat these crop species. The same cannot be said for the other crop species where damage was also not recorded (i.e., Deccan hemp, Bengal gram, cowpea, mustard, chillies, brinjal and tomato), as there were few fields of these crops and the fields were in areas not very accessible to blackbuck. Hence, the unpalatability of these crop species to blackbuck cannot be completely ruled out.

The intensity of damage in sorghum, foxtail millet, groundnut and redgram was reduced gradually as the distances from Enclosure-I increased (negative correlation: Pearson's r= 0.434, P=0.001 for all species combined). For cotton, there was a positive correlation for the same (r=0.329, P=0.054), i.e., further the distance, the more the damage. This again suggests that the damage to cotton was caused by livestock, and not blackbuck.

Discussion

Many factors influence the nature and extent of crop damage by blackbuck in a particular area. One of the most obvious would be the population size of blackbuck. Complaints of crop damage hardly occurred earlier when the blackbuck population at RWS was 17 animals in 1985 and 35 in 1987. In addition to blackbuck densities, the distance of the crop fields from the blackbuck area also determines the extent of damage, i.e., the more the distance of the crop fields from the blackbuck frequented areas, the less would be the damage. In general, damage was recorded within 200 m of the northern and southern borders of Enclosure-I, (intensive cropping areas) and one kilometre off the eastern and western borders (marginal cropping areas, interspersed with grazing lands). Blackbuck stray less into intensive crop areas due to the dense crop cover, relatively higher presence of humans, and absence of safe open areas to wander or retreat into, unlike in marginal cultivation. Crop fields that are close to the enclosure, or those situated near areas in grazing land frequented by blackbuck are more prone to crop damage.

Table 3
EXTENT AND DISTRIBUTION OF CROP DAMAGE

Species	Quadrat-wise (For sample sizes, see text)	Plant-wise (For sample sizes, see text)
Groundnut	20.0	9.6
Redgram	27.8	12.0
Greengram		
(monsoon crop)	-	14.3
(summer crop)	-	79.9
Blackgram		
(monsoon crop)	-	0.0
(summer crop)	-	50.0
Foxtail Millet	48.0	18.0
Sorghum		
(0-30 cm ht)	34.5	20.0
(31-75 cm ht)	19.2	9.9
(>76 cm ht)	20.0	14.4
Sesamum	-	0.6
Cotton	7.5	3.6

Note: - = Not done: plants too few and/or scattered.

Quadrat-wise: Indicates frequency of damage
Plant-wise : Indicates intensity of damage

The availability of a crop would also determine the extent of crop damage. Highly preferred species grown on a small scale would record greater damage than if the crop was grown on a large scale. The availability of the preferred crop also plays a role in determining the damage to less preferred species, especially if grown in close proximity to each other. This fact has applications in agriculture,

where decoy crops are grown to prevent or reduce damage to the intended crop. This may explain why damage was not recorded in species like Bengal gram, paddy, til and mustard at Rollapadu, which are reported to be eaten by blackbuck in other areas (Ranjitsinh 1989, Prasad and Ramana Rao 1990, Chandra 1997). Or it could be that the findings obtained by them were erroneous as they were largely based on enquiries from farmers.

The factors influencing crop damage mentioned above could be offset by factors like barriers, crop protection measures and the presence of people. We found that broad and deep trench-cum-mound walls, checkdams and dense vegetation acted as barriers to blackbuck movement. Though the blackbuck is known to jump long distances, it was observed at RWS that they do not jump across broad and deep TCM walls, especially those that are buffered by dense and tall vegetation. Tall non-palatable or non-preferred crops also serve as barriers, especially for smaller preferred crops. For example, greengram and blackgram when grown scattered in fields of redgram or sesamum were not damaged, while exposed pure stands were heavily or even totally damaged.

Many of the cases of crop damage recorded could be partially or totally due to livestock, rather than by blackbuck. Much of the damage occurs due to straying of livestock into crop fields, as many crop fields adjoin grazing land. In fields that are tilled, damage by draught bulls is likely if they are unmuzzled, or if the muzzles are defective. Damage may also occur when the bullocks graze in the adjoining fallow fields or grazing land during rest and then stray into the crop fields. In many cases, we were sure that the damage was by livestock, from actual sightings; by the presence of their hoof marks in crop fields; and in case of cow and buffalo damage, by the nature of the damage. Humans too may be responsible for some of the loss recorded. For example, in the case of greengram grown in mixed fields, workers may pull off some unripe pods to eat and the blame may be attributed to blackbuck by the farmers.

Adoption of crop protection measures at RWS is rare and of recent occurrence. In general, it was seen (i) in the crop fields of rich farmers (by employing watchmen); (ii) in small family holdings where the stakes are high (especially where well-irrigation is done); (iii) in good soil areas (yields would be more and assured than in poor soils); and, (iv) in areas close to villages (proximity and safety). In most other cases, except for scarecrows, fields were largely left unguarded.

Conclusion and Recommendations

The findings show that crop damage by blackbuck at Rollapadu Wildlife Sanctuary is of a serious nature and could worsen if measures to combat this problem are not taken immediately. Complaints from farmers are frequent. Their ire has also been redirected to the great Indian bustard (for which the Sanctuary was established) and the Sanctuary in general. After the problem of crop damage started, villagers talk of not wanting the Sanctuary, till recently a matter of pride for them. The Forest Department has still not taken measures to tackle the problem.

It is also evident from the study that some of the crop damage blamed on blackbuck (wantonly or due to ignorance) was actually caused by livestock. Some crop species are most likely not eaten at all by blackbuck (e.g. cotton). Thus, the Forest Department official in charge of RWS (and other such sanctuaries which have crop damage problems by blackbuck) should have an idea of crops that are palatable or non-palatable to blackbuck, should make actual visits to the crop fields to look for livestock signs in damaged fields, before attending to claims for crop damage compensation.

Based on the studies the following recommendations are given:

1. A crop damage compensation scheme should be started without delay. This would, to some extent, help to temporarily alleviate the grievances of the farmers.

2. Restricting the population of blackbuck to about 100 animals — either by culling or translocation. It is likely that with a population of 100 animals, the extent of crop damage would be small, judging from the past and present blackbuck populations and the history of crop damage at RWS. The topic of culling is of course a sensitive issue, and will be a major policy decision, needing the approval of the Ministry of Environment and Forests and changes in the Wildlife (Protection) Act. Interestingly, culling of blackbuck to reduce crop damage was practised earlier in India. The Raja of Wankaner has fixed a quota of blackbuck that had to be culled to prevent excess damage to crops in his region (Ranjitsinh 1982).

3. Fencing or hedging with *Gliricidia maculata* at the southern and northern borders of Enclosure-I. *Gliricidia maculata* is recommended since (i) it was found to be very successful in plantations at Nannaj, Solapur dist. Maharashtra, which has similar soil and climatic conditions; (ii) it would benefit farmers as it is a legume and its leaves are reported to be used as manure in some southern states of India. The fence or hedge would act as a barrier for blackbuck entering crop fields in these areas. Additionally, or as an alternative, broadening and deepening of the existing TCM walls could be done in these two regions. These two zones are intense agricultural areas, and the essential movement of blackbuck in summer out of Enclosure-I is mainly through and beyond areas in the eastern and western parts of Enclosure-I. These steps would minimise crop damage in fields to the north and south of Enclosure-I. For the marginally cultivated eastern and western areas, *Gliricidia* saplings may be given to farmers to be planted around individual fields.

4. The following are the changes suggested in cropping pattern to reduce crop damage:

a) Preferred species should be grown as far away from the enclosures as possible.

b) Non-palatable species, such as cotton, mulberry, paddy (where irrigation facilities are available) should be grown closer to the enclosures. Additionally, tall non-palatable species such as sesamum and sunflower could be grown closer to enclosures to serve as physical barriers to prevent access of blackbuck to preferred/palatable species grown further away.

c) Short and preferred crops like greengram and blackgram should be grown either in mixed fields of redgram or sesamum, or surrounded by a dense hedge of these two species.

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References

Chandra, J. (1997): Crop damage caused by blackbucks at Karera Great Indian Bustard Sanctuary, and possible remedial solutions. *J. Bombay nat. Hist. Soc. 94*: 322-332.

Chauhan, N. P. S. & V. B. Sawarkar (1989): Problems of over-abundant populations of nilgai and blackbuck in Haryana and Madhya Pradesh. *Indian Forester 115(7)*: 488-493.

Chauhan, N. P. S. & R. Singh (1990): Crop damage by overabundant populations of nilgai and blackbuck in Haryana (India) and its management. *Proc. 14th Verteb. Pest Conf.* (Eds. L.R. Davis & R. E. Marsh), University of California, Davis.

Manakadan, R. & A.R. Rahmani (1989): Rollapadu Wildlife Sanctuary. *J. Bombay nat. Hist. Soc. 86*: 368 - 380.

MANAKADAN, R. & A.R. RAHMANI (1993): A decade of conservation of the great Indian bustard at Rollapadu Wildlife Sanctuary. *Proc. Changing Scenario of Bird Ecology and Conservation* (Eds. A. Verghese *et al.*), Bangalore, Nov 1993. Ornithological Society of India, Bangalore. pp. 1-3.

MANAKADAN, R. & A.R. RAHMANI (1997): Rollapadu Wildlife Sanctuary. *In*: A Study of the Ecology of Grasslands of the Indian Plains with Particular Reference to their Endangered Fauna. Final Report, pp:549 (Ed: A. R. Rahmani). Bombay Natural History Society, Mumbai. pp. 117-180.

MOWER, K.J., T.W. TOWNSEND & W.J. TYZNIK (1997): Sample sizes to measure young apple trees browsed by deer in Ohio. *Wildlife Society Bulletin 25*: 344-347.

PRAKASH, I. (1990): Dilemma of ungulate conservation in Rajasthan Desert. *Conservation in Developing Countries: Problems and Prospects* (Eds. J.C. Daniel & J.S.Serrao), Bombay Natural History Society, Bombay. pp. 402-410.

PRASAD, N.L.N.S & J.V. RAMANA RAO (1990): Blackbuck conservation in Andhra Pradesh. *In* Proc. *Conservation in Developing Countries: Problems and Prospects* (Eds. J.C. Daniel & J.S. Serrao), Bombay Natural History Society, Bombay. pp. 400-406.

RAHMANI, A. (1985): Threats to the Karera Bustard Sanctuary: Recommendations for Conservation. Technical Report No. 6. Bombay Natural History Society, Bombay.

RANJITSINH, M.K. (1989): The Indian Blackbuck. Natraj Publishers, Dehra Dun.

SCHULTZ, Bo (1986): The management of crop damage by wild animals. *Indian Forester 112 (10)*: 891-899.

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